Studies on Physico-chemical Properties of Turkish Wild Stone Pine (Pinus pinea L.) Kernel and Pits

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Abstract: The physical and chemical properties were determined in developing stone pine (Pinus pinea) fruits from Balya (Balikesir) to investigate potential uses. Completely ripe kernels contained crude oil, crude protein, ash, crude fibre, crude energy, ether-soluble extract and minerals including Ca, Mn, Na, Ni, S, Se, Ti, V and Zn as major minerals. Also, physical properties such as length, thickness and width, mass of 1000 kernel, projected area, porosity, bulk and true density, terminal velocity, at different surface static friction coefficient and rupture forces (hardness for kernel) of stone pine pits and kernels were measured. The mineral content of stone pine was established determined by ICP-AES. In general, moisture, crude protein, crude oil, ash, ether-soluble extract, Ca, Mn, Na, Ni and Zn contents of Balya stone pine kernels were found as 66.7 %, 32.1%, 42.57%, 4.35%, 37.03%, 256.64 ppm, 531.22 ppm, 1471.66 ppm, 3020.95 ppm and 10122.16 ppm. As a result, it is very great interest to knowledge the mineral contents of stone pine kernels. In stone pine pits, rupture strength of stone pine kernels decreased and hardness of stone pine kernels decreased as the moisture content increased. The porosity decreased of stone pine pit and the porosity increased of stone pine kernel as the moisture content increased.

Key words: Stone pine • Pinus pinea • Physical and chemical properties • Minerals

INTRODUCTION

Stone pines are fruits of Pinus pinea L. belong to Pinaceae family. It is one of the popular tree nuts. The species of genus Pinus are cultivated in the Asia, Europe, the Near East, North America and Mediterranean countries, mainly in Spain, Portugal, Italy, Greece, Albania and Turkey. About 50% of this area is found in highlands of Bergama-Kozak in İzmir [1]. The total area covered by stone pine woodlands is 380,000 ha (75% Spain, 9% Portugal, 9% in Turkey, 5% in Italy and lower percentages in Greece, Lebanon and France. Stone pine kernels are used in the Mediterranean as a culinary delicacy and have a protein value) [2]. Several species produce nuts, which today are considered to be a delicacy, that are ingredients in a wide variety of traditional dishes and are important in international trade. There are about twelve species of pines that bear edible nuts but the only important commercial species in Pinus pinea. Pine nuts were also used in sausage, salads, turnover sweets and as seasoning for boiled bulbs and various sauces [3].

The trees can stand strong winds and salt sea air and once established will tolerate both wet and dry conditions. European pine nuts, commonly called pignolia nuts, are obtained primarily from the stone pine, Pinus pinea and native to northern Mediterranean regions. These seeds are 1 cm in length and are rich in oil. Pine nuts-small, edible seeds extracted from the cones of various Pine species, have been eaten worldwide as a flavorful, protein and oil reach food [4]. Acun [5] and Nergiz and Dönmez [1] reported that the Turkish production of pine nut is about 1,200-1300 tons/year. Nine hundred tons of this production is obtained only in the highlands of Bergama-Kozak, which is in the Aegean region of Turkey. Stone pine kernels can be eaten both raw and roasted. Kernels are included as ingredients in a variety of traditional dishes, such as breads, candies, sauces and cakes, as well as vegetable and meat dishes.

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Pine kernels have a potential source of nutrients [1,5,6].
Limited studies on chemical composition of the Pipinea
kernel were conducted [1,7,8]. There have been no studies
concerning the physical and aerodynamic properties of
stone pine (P. pinea) kernels growing in Turkey. The aim
of this study was to establish the some chemical
composition and physical properties of stone pine kernels
such as dimensions, mass, bulk density, true density,
porosity, static friction coefficient on various surfaces
and terminal velocity.

**MATERIALS AND METHODS**

**Material:** Pine fruits were collected from Balya (Balikesir)
province in October 2003. They were kept in cooled bags
for transport to the laboratory. The fruits were cleaned to
remove all foreign matter such as dust, bruch, leaves,
immature and damaged kernels. Ripe wet mature stone
pine (P. pinea) kernels were used for the study. The initial
moisture content of samples was determined by air
convection oven at 103±2 °C until a constant mass was
reached [9]. The remaining kernels were packed in a sealed
glass jar (3000 ml) and kept in cold storage (+4 °C) for 10
days to enable the moisture to distribute uniformly
throughout the product.

**Chemical Analyses:** The nutritional properties of kernels
were determined by the method of AOAC [10] and
Cemeroğlu (1992). After the kernels were prepared for
proximate analyses, all minor elements were determined
using an ICP-AES (Vista series, Varian International AG,
Switzerland). The properties of this instrument are as
follow outlined by Skujins [11]. The samples were
analyzed for crude energy with an adiabatic oxygen bomb
calorimeter. Triplicate samples were used to establish
chemical composition.

**Determination of Mineral Contents:** About 0.5 g dried
and ground sample was put into burning cup and 10 mL
pure HNO₃ was added. The sample was incinerated in
MARS 5 Microwave Oven under the 170 psi at 200°C
temperature and solution diluted 25 mL with water.
Samples were filtered in filter paper and were determined

**Working Conditions of ICP-AES**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>ICP-AES (Varian-Vista</th>
<th>0.7-1.5 kw (1.2-1.3 kw for Axial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Power</td>
<td></td>
<td>10.5-15 L/min. (radial)</td>
</tr>
</tbody>
</table>

Auxiliary gas flow rate (Ar): 1.5 “ (axial)
Viewing height: 5-12 mm
Copy and reading time: 1-5 s (max. 60 s)
Copy time: 3 s (max. 100 s)

**Determination of Physical- Aerodynamic Properties:**
Stone pine pits and kernels were assessed at 6.41-24.53%
and 4.84-33.33% moisture contents (d.b.) respectively,
because the processing with these products is usually
carried out between these moisture content values. For
each moisture content, the length, width, thickness and
mass of stone pine pits and kernels were measured in
randomly selected 100 stone pine pits and stone pine
kernels. Dimensional properties of kernels were measured
by a micrometer to an accuracy of 0.01mm. The mass of
kernels and thousand kernels mass were measured by an
electronic balance to an accuracy of 0.001 g. To evaluate
1000 grain mass, 100 randomly selected kernels from the
bulk were averaged.

Geometric mean diameter (D₃) and sphericity (O)
values were found using the following formula [12,13];

\[ D₃ = (LWT)^{0.333} \]

\[ O = (LWT)^{0.333} / L \]

The stone pine pit and kernel true density (ρ₀, ρₖ), as
a function of moisture content, were determined using the
liquid displacement method. Toluene (C₆H₆) was used
rather than water because it is absorbed by grains to a
lesser extent. Also, its surface tension is low, so that it
fills even shallow dips in a grain and its dissolution power
is low [14-16].

The bulk density (ρₖ) was determined with a mass per
hectoliter tester which was calibrated in kg per hectoliter
[13,17,18]. The kernels were removed by a strike off stick.
The kernels were not compacted in any way.

The porosity (ε) was determined by following equation;

\[ ε = 1 - ρₖ / ρ₀ \]

in which ρ₀ and ρₖ are the bulk density and the true
density, respectively [12].

The terminal velocities of stone pine and kernel at
different moisture content were measured using an air
column (Fig. 1). For each test, a sample was dropped into
the air stream from the top of the air column, up which air
was blown to suspend the material in the air stream. The
Fig. 1: Unit for measuring terminal velocity

Fig. 2: Biological material test unit (B.M.T.U.)
Table 1: The chemical properties and mineral contents of stone pine kernel* N x 0.25

<table>
<thead>
<tr>
<th>Chemical properties</th>
<th>Values</th>
<th>Mineral contents (mg/kg)</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>33.33</td>
<td>Co</td>
<td>0.21</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>32.10</td>
<td>Cr</td>
<td>4.69</td>
</tr>
<tr>
<td>Crude oil (%)</td>
<td>42.57</td>
<td>Cu</td>
<td>20.42</td>
</tr>
<tr>
<td>Crude fibre (%)</td>
<td>9.52</td>
<td>Fe</td>
<td>87.63</td>
</tr>
<tr>
<td>Crude energy (KCal/100g)</td>
<td>6958.00</td>
<td>Mn</td>
<td>5152.23</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>4.35</td>
<td>Na</td>
<td>1471.66</td>
</tr>
<tr>
<td>Ether-soluble extract (%)</td>
<td>37.03</td>
<td>Ni</td>
<td>3020.95</td>
</tr>
<tr>
<td><strong>Mineral contents (mg/kg)</strong></td>
<td></td>
<td><strong>S</strong></td>
<td>44481.76</td>
</tr>
<tr>
<td>Al</td>
<td>43.63</td>
<td>Se</td>
<td>79.12</td>
</tr>
<tr>
<td>As</td>
<td>11.99</td>
<td>Sr</td>
<td>26.19</td>
</tr>
<tr>
<td>B</td>
<td>21.97</td>
<td>Ti</td>
<td>714.38</td>
</tr>
<tr>
<td>Bi</td>
<td>0.78</td>
<td>Y</td>
<td>1580.82</td>
</tr>
<tr>
<td>Ca</td>
<td>256.64</td>
<td>Zn</td>
<td>1012.16</td>
</tr>
<tr>
<td>Cd</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Dimensional properties of stone pine pits*

<table>
<thead>
<tr>
<th>Properties</th>
<th>Moisture values (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (mm)</td>
<td>6.41</td>
</tr>
<tr>
<td>Width (mm)</td>
<td>11.34</td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>18.22</td>
</tr>
<tr>
<td>Mass (g)</td>
<td>24.53</td>
</tr>
<tr>
<td>Geometric mean diameter (mm)</td>
<td>10.38±0.060</td>
</tr>
<tr>
<td>Sphericity (-)</td>
<td>50.22±0.335</td>
</tr>
</tbody>
</table>

*All data represent the mean of hundred pit values

Table 3: Dimensional properties of stone pine kernels*

<table>
<thead>
<tr>
<th>Properties</th>
<th>Moisture values (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (mm)</td>
<td>4.84</td>
</tr>
<tr>
<td>Width (mm)</td>
<td>11.57</td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>20.18</td>
</tr>
<tr>
<td>Mass (g)</td>
<td>33.33</td>
</tr>
<tr>
<td>Geometric mean diameter (mm)</td>
<td>7.26±0.037</td>
</tr>
<tr>
<td>Sphericity (-)</td>
<td>50.48±0.284</td>
</tr>
</tbody>
</table>

*All data represent the mean of hundred kernel values

Table 4: The correlation coefficient of stone pine pits and kernels

<table>
<thead>
<tr>
<th>Material</th>
<th>Parameters</th>
<th>Ratio</th>
<th>Degrees of from</th>
<th>Correlation coefficient (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone pine pit (n= 641%)</td>
<td>$L_e/W_e$</td>
<td>2.02</td>
<td>98</td>
<td>0.203</td>
</tr>
<tr>
<td></td>
<td>$L_e/T_e$</td>
<td>2.39</td>
<td>98</td>
<td>0.191</td>
</tr>
<tr>
<td></td>
<td>$L_e/M_e$</td>
<td>26.73</td>
<td>98</td>
<td>0.600*</td>
</tr>
<tr>
<td>Stone pine kernel (n= 484%)</td>
<td>$L_e/W_e$</td>
<td>2.49</td>
<td>98</td>
<td>0.056</td>
</tr>
<tr>
<td></td>
<td>$L_e/T_e$</td>
<td>3.13</td>
<td>98</td>
<td>0.074</td>
</tr>
<tr>
<td></td>
<td>$L_e/M_e$</td>
<td>64.04</td>
<td>98</td>
<td>0.461*</td>
</tr>
</tbody>
</table>

*Significant at the level 1%
material test device was used (Fig. 2). The device, developed by Aydin and Çağat [24], has three main components which are stable up and motion bottom of platform, a driving unit (AC electric motor and electronic variator) and the data acquisition (Dynamometer, amplifier and XY recorder) system. The rupture force of kernel was measured by the data acquisition system. The stone pine pit and kernel was placed on the moving bottom platform and was pressed with stationary platform. Probe used with 2 mm diameter in experiment for hardness of kernels was connected to dynamometer. Experiment was conducted at a loading velocity at 50 mm min⁻¹. The variance analysis was made in dimensions of stone pine pit and kernel for different moisture levels [25].

RESULTS AND DISCUSSION

The Chemical Properties and Mineral Contents: The chemical properties of stone pine (P. pinea L.) fruits from Balya (Balikesir) to investigate uses are given in Table 1. The moisture, crude protein, crude oil, crude fibre, ash, crude energy and ether-soluble extract values of stone pine kernel collected from Balya region were 33.33%, 32.10%, 42.57%, 9.52%, 4.35%, 6098 kcal/100g and 37.03%. Also, major minerals contents (ppm) of Balya sample were established as 256.64 for Ca, 531.223 for Mn, 1471.66 for Na, 3020.95 for Ni, 4448.76 for S, 714.38 for Ti, 1580.82 for V and 10122 for Zn.

Dry matter, crude protein, crude oil, ash, ether-soluble extract, some mineral contents of Balya stone pine kernels were found similar to those in some references [1,7,8]. Also, Ca, Cu and Na values were clearly higher according to findings to Nergiz and Dönmez [1]. The chemical composition of stone pine indicates significance differences depending on environmental, growth conditions and region. Other researchers have concluded these properties for various kernel and fruits such as stone pine [7,8,25,26], neem nut [27], shea kernel [28], peanut [29], apricot pit and its kernel [30,31] and terebinth fruits [32,33].

The essential role of selenium (Se) for human health has been well established in recent years. Selenium has an active suggested as a modulator in inflammatory and immune responses [34,35]. Cadmium is the major component of bone and assists in teeth development [36]. This work attempts to contribute to knowledge of the nutritional properties of these kernels. However, knowledge of their mineral contents of condiments is of great interest.

The Physical-Aerodynamic Properties

Stone Pine Pit and Kernel Dimensions and Grain Distribution: The dimensional properties of stone pine pits and their kernels were given in Table 2 and Table 3 respectively. 82% of stone pine pits have a length ranging from 16.43 to 19.00 mm, 9.0% of stone pine pits have a length less than 16.43 mm and 9.0% of stone pine pits have a length more than 19.00 mm at a moisture content of 4.61%. The relationships between length, width, thickness and mass were given by the following equation.

\[ L_p = 2.016 W_p = 2.386 T_p = 26.728 M_p \]

78.0% of stone pine kernels have a length ranging from 13.23 to 15.26 mm, 9.0% of stone pine kernels have a length less than 13.23 and 13% of stone pine kernels have a length more than 15.26 mm at a moisture content of 4.84%. The relationships between length, width, thickness and mass of stone pine kernels were given by the following equation.

\[ L_k = 2.489 W_k = 3.126 T_k = 64.044 M_k \]

The correlation coefficient of these relationships of stone pine pits and kernels are given in Table 4. The relationships between \( L_p / W_p \) and \( L_p / T_p \) of stone pine pits and \( L_k / W_k \) of stone pine kernels have been found to be statistically significant.

The length, width, thickness, mass and geometric mean diameter values of stone pine pits and kernels increased depending on increasing moisture content. The reasons of increasing length, width, thickness, mass and geometric mean diameter values of stone pine pits and kernels depending on increasing moisture content can probably be speculated some tiny air voids on the grains. The similar results were found by Deshpande et al. [17] for soybeans, Baryeh [37] for cambata groundnuts.

Sphericity: The sphericity value of stone pine pit was found as follow; 0.5922 sphericity value at 6.41 %; 0.6018 sphericity value of 11.34 %; 0.6044 sphericity value at 18.22 %; 0.6058 sphericity value at 24.53 % moisture content respectively. There were positive correlation between the sphericity value of stone pine pit and the moisture content. The relationship between sphericity and moisture content in stone pine pits was found to be the following;
The sphericity value of stone pine kernel ranges were found; 0.5048 at 4.84% e; 0.5101 at 11.57; 0.5180 at 20.18% and 0.5243 at 33.33% moisture content respectively.

The relationship between sphericity and moisture content in stone pine kernel was found to be the following,

\[ \Omega_s = 0.502 + 0.000691 m_e (R^2 = 0.978) \]

An increasing relationship was found between sphericity and moisture content in stone pine kernels. Desphande et al. [17] have found an increasing relationship between sphericity and moisture content up to moisture content of 25% in their experiments with soybean.

**Thousand Grain Mass:** The dependence of 1000 grain mass of stone pine pits and kernels on moisture content was found to be between 617.8 g and 777.3 g and 228 g and 319.6 g respectively (Fig. 3).

An increasing relationship was found between 1000 kernel mass and moisture content in stone pine pits and kernels. The equations are as follows,

\[ m_{1000p} = 579.2 + 8.29 \, m_e (R^2 = 0.953) \]
\[ m_{1000k} = 211.7 + 3.26 \, m_e (R^2 = 0.998) \]

Similar results were found by Desphande et al. [17] for soybeans; Öğüt [15] for lupin seeds and Singh and Goswami [16] for cumin seeds.

**Bulk Density:** While the bulk density of stone pine pits was 553.0 kg/m³ at a moisture content of 6.41%, it increased to 583.1 kg/m³ at a moisture content of 24.53% (Fig. 4). The relationship between bulk density of stone pine pits and moisture content was found to be as follows,

\[ \rho_b = 542.9 + 1.71 m_e (R^2 = 0.979) \]

In stone pine kernels, while the bulk density was 486.8 kg/m³ at a moisture content of 4.84%, it increased to 523.1 kg/m³ at a moisture content of 33.33%. The relationship between them was found to be as follows;

\[ \rho_k = 487.5 + 1.22 m_e (R^2 = 0.823) \]

As the moisture content increased so the bulk density values increased in coffee seeds [38], in pumpkin seeds [19] and in karingda seeds [18]. However, as the moisture content increased, the bulk density values decreased in lupin seeds [15], in soybean [17] and in sunflower seeds [39].

**True Density:** The volume mass of stone pine pit and kernel varied between 1155.5 kg/m³ and 1247.0 kg/m³ and 1117.2 kg/m³ and 1160.3 m³ respectively (Fig. 5). The relationship between volume mass and the moisture content was found to be the following;

\[ \rho_v = 1130.8 + 4.78 \, m_e (R^2 = 0.971) \]
\[ \rho_k = 1119 + 1.44 \, m_e (R^2 = 0.789) \]

Öğüt [15] for lupin; Singh and Goswami [16] for cumin; Gupta and Das [39] for sunflower; Chandrasekar and Visvanathan [38] for coffee and Aviara et al. [40] for guna found similar results.

**Terminal Velocity:** Terminal velocities of stone pine pits and stone pine kernels varied between 6.62 m/s and 7.68 m/s, 5.92 m/s and 6.59 m/s respectively (Fig. 6). The relationship between terminal velocity and moisture content was found as the following:

\[ v_p = 6.29 + 0.0579 \, m_e (r = -0.994) \]
\[ v_k = 5.94 + 0.0157 \, m_e (r = 0.795) \]

As the moisture content of grains increased, so the values of terminal velocity increased. Joshi et al. [19] for pumpkin for lentil found similar results.

**Projected Area:** Projected areas varied between 0.44 cm² and 1.59 cm² and 1.00 cm² and 1.04 cm² for stone pine pits and for stone pine kernels respectively. Projected areas of stone pine pit and stone pine kernel are given in Fig. 7. As moisture content increased, so did the projected areas. The relationship between projected area and moisture content of stone pine pit and stone pine kernel was found to be as follows;

\[ P_{ap} = 1.40 + 0.0081 \, m_e (R^2 = 0.948) \]
Fig. 3: 1000 grain mass versus moisture content

Fig. 4: Bulk density variation with moisture content

Fig. 5: True density versus of moisture content
Fig. 6: Terminal velocity variation with moisture content

Fig. 7: Projected area variation with moisture content

Fig. 8: Porosity variation with moisture content
Fig. 9: Coefficient of static friction versus moisture content

Fig. 10: Variation of rupture force of stone pine pits versus moisture content

Fig. 11: Variation of hardness of stone pine kernels versus moisture content
\[ P_{\text{h}} = 1.00 + 0.0014 \ m_{\text{k}} \ (R^2 = 0.730) \]

Desphande et al. [17] for soybean have found similar results.

**Porosity:** The variations of porosity values depending on moisture content in stone pine pit and in stone pine kernel are shown in Fig. 8. The porosity values of stone pine pits at moisture contents of 6.41 and 24.53% varied between 51.97% and 52.52%. The relationship between porosity value and moisture content was found to be as follows:

\[ \varepsilon = 51.80 + 0.031 \ m_{\text{k}} \ (R^2 = 0.976) \]

Gupta and Das [39] for sunflower and Öğüt [15] for lupin, stated that as the moisture content increased so the porosity value increased.

In stone pine kernel, the porosity values at moisture contents of from 4.84% to 33.33% vary between 56.42% and 54.85%. There is a negative relationship between porosity and moisture content. This relationship is given by the following equation:

\[ \varepsilon = 56.60 - 0.0574 \ m_{\text{k}} \ (R^2 = 0.904) \]

Suthar and Das [18] for karingda seeds, Chandrasekar and Visvanathan [38] for coffee, Desphande et al. [17] for soyabeans, and Joshi et al. [19] for pumpkin seeds have found similar results.

**Coefficient of Static Friction:** The variation of the coefficient of static friction with moisture content in stone pine pit and stone pine kernel are given in Fig. 9 for galvanized steel sheet and plywood sheets. It can be seen from the figure that the coefficient of static friction values on a galvanized steel sheet and one plywood sheet increased with increasing moisture content. This relationship was found to be as follows:

\[ \mu_{\text{g}} = 0.304 + 0.0057 \ m_{\text{k}} \ (R^2 = 0.913) \]

(for galvanized steel sheet)

\[ \mu_{\text{p}} = 0.474 + 0.0022 \ m_{\text{k}} \ (R^2 = 0.990) \]

(for plywood sheet)

The relationship between stone pine kernel and moisture content was found to be as follows:

\[ \mu_{\text{k}} = 0.309 + 0.0019 \ m_{\text{k}} \ (R^2 = 0.931) \]

(for galvanized steel sheet)

\[ \mu_{\text{b}} = 0.458 + 0.0028 \ m_{\text{k}} \ (R^2 = 0.987) \]

(for plywood sheet)

Öğüt and Çarman [41]; Joshi et al. [19]; Tsang-Mui-Chung et al. [42]; Öğüt [15] stated that as the moisture content increased so the coefficient of static friction increased.

**Rupture Strength and Hardness:** Rupture strength values of stone pine pit and hardness values stone pine kernel are given in Fig. 10 and 11, respectively. Rupture strength values of stone pine pit decreased as the moisture content increased. The study of Güner et al. [43] supported this result.

In stone pine pit, the force applied through length was the biggest and it was followed by the one applied through thickness and width. This difference may be attributed to physical properties of stone pine pit. The relationship between rupture strength values and moisture content was found to be as follows:

\[ F_{\text{m}} = 712.59 - 12.585 \ m_{\text{k}} \ (R^2 = 0.940) \]

\[ F_{\text{w}} = 479.89 - 7.624 \ m_{\text{k}} \ (R^2 = 0.969) \]

\[ F_{\text{w}} = 328.42 - 8.517 \ m_{\text{k}} \ (R^2 = 0.880) \]

Hardness values of stone pine kernel decreased as the moisture content increased. The relationship between hardness values and moisture content was found to be as follows:

\[ H_{\text{k}} = 15.882 - 0.1091 \ m_{\text{k}} \ (R^2 = 0.987) \]

**CONCLUSION**

- The dimensional properties and mass of stone pine pit and stone pine kernel increased depending on moisture content. This situation stems from water absorption of pit and kernel.
- While the sphericity value of stone pine pit showed a slight decreasing trend depending on moisture content, the sphericity value of stone pine kernel increased with increasing moisture content.
- In stone pine pit and stone pine kernel, 1000 grain mass, terminal velocity, bulk and true density and projected area increased with moisture content.
- While the porosity value showed a decreasing relationship with moisture content for stone pine pit,
porosity value increased with moisture content in stone pine kernel.

- In stone pine pit and stone pine kernel, the coefficient of static friction was found to be higher on a plywood sheet than on a galvanized steel sheet. The value of coefficient of static friction on both surfaces of stone pine pit increased with moisture content.

- A negative relationship was found between rupture strength values of stone pine pit and stone pine kernel and moisture content. That is, as the moisture content increased the rupture strength decreased. While the force applied through length was found to be highest in stone pine pit, it was found to be highest through thickness in stone pine kernel.

- This work attempts to contribute to knowledge of the nutritional properties of these kernels. However, knowledge of their mineral contents of condiments is of great interest.

- It is thought to be helping the fruit processing technology to be known the chemical composition of P. pinea kernels.

**NOMENCLATURE**

- $p$ = Stone pine pit
- $k$ = Stone pine kernel
- $L_p$ = Length of stone pine pit (mm)
- $L_k$ = Length of stone pine kernel (mm)
- $W_p$ = Width of stone pine pit (mm)
- $W_k$ = Width of stone pine kernel (mm)
- $t_p$ = Thickness of stone pine pit (mm)
- $t_k$ = Thickness of stone pine kernel (mm)
- $M_p$ = Mass of stone pine pit (g)
- $M_k$ = Mass of stone pine kernel (g)
- $O_p$ = Sphericity of stone pine pit
- $O_k$ = Sphericity of stone pine kernel
- $m_p$ = Moisture content stone pine pit (%).d.b.
- $m_k$ = Moisture content stone pine kernel (%).d.b.
- $m_{100p}$ = Thousand of stone pine pit (g)
- $m_{100k}$ = Thousand of stone pine kernel (g)
- $ρ_{p}$ = Bulk density of stone pine pit (kg/m³)
- $ρ_{k}$ = Bulk density of stone pine kernel (kg/m³)
- $ρ_o$ = True density of stone pine pit (kg/m³)
- $ρ_c$ = True density of stone pine kernel (kg/m³)
- $V_p$ = Terminal velocity of stone pine pit (m/s)
- $V_k$ = Terminal velocity of stone pine kernel (m/s)
- $PA_p$ = Projected area of stone pine pit (cm²)
- $PA_k$ = Projected area of stone pine kernel (cm²)
- $ε_p$ = Porosity of stone pine pit (%)  
- $ε_k$ = Porosity of stone pine kernel (%)  
- $μ_p$ = Coefficient of static friction of stone pine pit  
- $μ_k$ = Coefficient of static friction of stone pine kernel  
- $F$ = Rupture force (N)  
- $H$ = Hardness (N)

**REFERENCES**